

### Section D. Piloting

#### **Overview**

#### Introduction

Piloting is directing a vessel by using landmarks, other navigational aids and soundings. Safe piloting requires the use of corrected, up-to-date charts. Piloting deals with both present and future consequences. Be alert and attentive. You must be consciously aware of where you are and where you soon will be.

#### In this section

These items are discussed in this section:

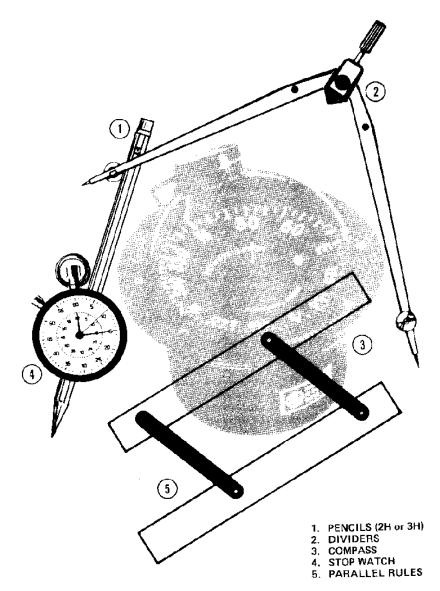
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### **Basic Piloting Equipment**

#### D.1. General

Adequate preparation is very important in piloting a boat. Piloting is the primary method of determining a boat's position. In order for a boat coxswain to make good judgment on all decisions in navigation, tools such as compasses, dividers, stopwatches, parallel rulers, pencils and publications must be available. (See Figure 14-22).



**Basic Piloting Tools Figure 14-22** 



#### **D.2.** Compass

For a boat, the magnetic compass is used to steer your course, give a constant report on your boat's heading, and is used as a sighting instrument to determine bearings.

A mark called a 'lubber's line' is fixed to the inner surface of the compass housing. Similar marks, called '90 degree lubber's line', are usually mounted at ninety degree intervals around the compass card - used in determining when an object is bearing directly abeam or astern. Centered on the compass card is a pin (longer than the lubber's line pins) and is used to determine a position by taking bearings on visible objects.

### D.3. Parallel rulers

Parallel rulers are two rulers connected by straps that allow the rulers to separate while remaining parallel. They are used in chart work to transfer directions from a compass rose to various plotted courses and bearing lines and vice versa. Parallel rulers are always walked so that the top or lower edge intersect the compass rose center to obtain accurate courses.

# D.4. Course plotter

A course plotter may be used for chart work in place of the parallel rulers discussed above. It is a rectangular piece of clear plastic with a set of lines parallel to the long edges, and semi-circular scales. The center of the scales is at or near the center of one of the longer sides and has a small circle or bull's eye. The bull's eye is used to line up on a meridian so that the direction (course or bearing) can be plotted or read off of the scale. A popular model is the "Weems Plotter" that is mounted on a roller for ease of moving.

#### D.5. Pencils

It is important to use a correct type of pencil for plotting. A medium pencil (No. 2) is best. Keep your pencils sharp; a dull pencil can cause considerable error in plotting a course due to the width of the lead.

#### **D.6.** Dividers

Dividers are instruments with two pointed legs, hinged where the upper ends join. Dividers are used to measure distance on a scale and transfer them to a chart.

#### D.7. Stopwatch

A stopwatch or navigational timer, which can be started and stopped at will, is very useful to find the lighted period of a navigational aid. This is usually done for purposes of identification. Also, it is used to run a speed check.



### D.8. Nautical slide rule

The Nautical Slide Rule will be discussed in the time, distance and speed section of this chapter.

# D.9. Drafting compass

The drafting compass is an instrument similar to your dividers. One leg has a pencil attached. This tool is used for swinging arcs and circles.

## D.10. Speed curve (Speed vs RPMs)

A speed curve is used to translate tachometer readings of revolutions per minute (RPMs) into the boat's speed through the water. A speed curve is obtained by running a known distance at constant RPM in one direction and then in the opposite direction. The time for each run is recorded and averaged to take account for current and wind forces. Using distance and time the speed is determined for the particular RPM. (See Figure 14-23)

Speed, Kts Calm Water	Approx. RPM	Fuel Gal/Hour	Consumption Gal/Mile	Cruise Radius/Miles
7.60	760	3.86	.51	882
7.89	1000	4.99	.63	712
9.17	1250	7.50	.82	550
9.48	1500	12.75	1.31	335
12.50	1750	16.80	1.35	333
15.53	2000	21.00	1.35	333
19.15	2250	33.00	1.72	261
21.34	2400	33.75	1.58	284

## Sample Speed vs RPMs Conversion Table Figure 14-23

#### D.11. Charts

Charts are essential for plotting and determining your position, whether operating in familiar or unfamiliar waters. Never get underway without the appropriate charts.

### D.12. Depth sounder

There are several types of depth sounders but they operate on the same principle. The depth sounder transmits a high frequency sound wave that reflects off the bottom and returns to the receiver. The 'echo' is converted to an electrical impulse and can be read from a visual scale on the depth sounder. It shows the depth of water you are in, it does not show the depth of water your are heading for.



#### D.12.a. Transducer

#### NOTE &

Always consider the location of the transducer, it is usually mounted above the lowest point of the hull.

The sound wave is transmitted by a device called a transducer. The transducer is usually mounted through the hull and sticks out a very short distance. It is not mounted on the lowest part of the hull. The distance from the transducer to the lowest point of the hull must be known. This distance must be subtracted from the depth sounding reading to determine the actual depth of water available.

Example: Depth sounder reading is 6 feet. The transducer is 1 foot above the lowest point of the hull - the boat extends 1 foot below the transducer. This 1 foot is subtracted from the reading of 6 feet which means your boat has 5 feet of water beneath it.

### D.12.b. Viewing the depth

#### NOTE &

To determine the actual water depth below the boat's hull subtract the distance between the transducer and the lowest point of the hull from all readings.

Water depth is indicated by a variety of methods:

- 1. Indicator: A digital display or a flashing light that rotates clockwise around a scale on a visual screen in the pilothouse. In the flashing light type, the first "flash" is when the pulse goes out and the second flash is the "echo" back which indicates the depth.
- 2. Recorder: Depths are recorded on paper tape.
- 3. Video display screen: The display is similar to a small television set with brightness on the bottom of the screen indicating the sea floor.

### D.12.c. Viewing bottom conditions

With practice and experience, you can also tell what the bottom characteristics and conditions are. Flashing light and video display sounders may be generally interpreted as:

- Sharp, clear flash hard bottom
- Broad, fuzzy flash soft, muddy bottom
- Multiple, fairly sharp flashes rocky bottom
- Additional flashes or displays at multiples of the least depth indicated may reveal the need to turn down the sensitivity control.

### D.12.d. Adjustment controls

Adjustment controls depend on the type of depth sounder. The operator's manual should be reviewed for correct use. Typical adjustment controls include depth scales (which may include feet and fathoms), and a sensitivity control.



#### D.13. Lead line

#### NOTE &

Always keep a lead line neatly stowed and ready for use in the event the depth sounder becomes inoperative. Depth of water is one of the most important dimensions of piloting. A hand-held lead line is used for ascertaining the depth of water when you don't have a depth sounder, when the depth sounder is not operational or you are operating in known shallow water.

It consists of a line marked in fathoms and a lead weight of 7 to 14 pounds, hollowed at one end in which tallow is inserted to gather samples of the bottom. It is simple and not subject to breakdown. Lead line limitations include:

- not useable in adverse sea conditions
- awkward to use
- usable only at slow speed.

# D.13.a. Lead line markings

#### NOTE &

Lead lines should be wetted and stretched prior to marking. Lead lines are marked as follows: (See Figure 14-24)

Depth	Lead line Marking
2 Fathoms	two (2) strips of leather
8 Fathoms	three (3) strips of leather
5 Fathoms	one (1) white rag (usually cotton)
7 Fathoms	one (1) red rag (usually wool)
10 Fathoms	one (1) strip of leather with a hole
18 Fathoms	three (3) strips of leather
15 Fathoms	one (1) white rag (usually cotton)
17 Fathoms	one (l) red rag (usually cotton)
20 Fathoms	two (2) knots
26 Fathoms	one (1) knot



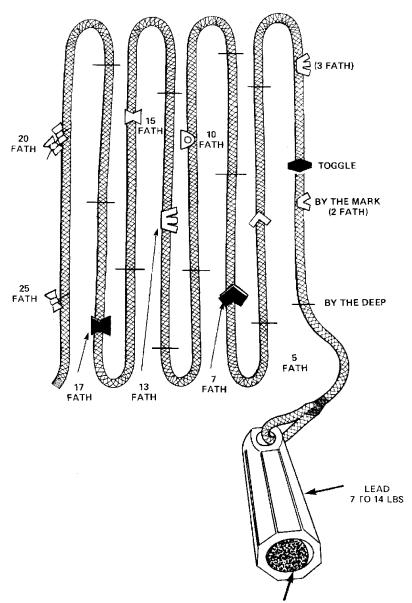


Figure 9-32 Handheld Leadlin GATHERS SAMPLES FROM BOTTOM; WHEN ARMED WITH TALLOW 9--50

#### Handheld Leadline Figure 14-24

D.13.b. Casting the hand-held lead line

The procedure below should be followed in casting a lead line:



Step	Procedure
1	Grasp the line by the toggle.
2	Swing the lead in a fore-and-aft arc.
3	When sufficient momentum is obtained and at shoulder level,
	throw the lead as far forward as possible.
4	Pull the slack out of the line until you feel the lead on the
	bottom.
5	When the line is straight up and down read the sounding.

# D.13.c. Reporting the soundings

There are two ways to report soundings, depending upon where the watermark is located on the lead line.

- 1. Depth that corresponds to any mark on the lead line is reported: "By the Mark", that is, should the depth align with the two strips of leather it would be reported "By the Mark 2".
- 2. Intermediate whole fathoms are called deeps. Report fractions of a fathom as halves and quarters, such as, (and a half seven) or (less a quarter ten).

### D.14. RDF and ADF

A radio direction finder (RDF) will allow you to take bearings on radio transmitters which are well beyond your visual range. One type of RDF requires manual operation to obtain bearings. The automatic radio direction finder (ADF) automatically takes and displays the bearings.

Radio bearings are not as accurate as visual bearings. It takes a great deal of experience to be able to effectively use the equipment. Be very careful when plotting radio bearings, especially in the correct direction.

### D.15. VHF-FM homer

The VHF-FM homer (direction finder homing device) allows you to aim in on the source of any FM radio signals you are receiving. This unit will also function as a backup VHF-FM receiver.

The VHF-FM homer measures the small difference in angle of a signal, from a known source and received by each antenna, then converts this signal into the angle of direction from your boat. This direction is shown on a swinging needle display screen mounted in the pilothouse. The source must continue to transmit for you to track it.



The procedure for using the homer is outlined below:

NOTE &

A needle centered in the middle of the screen may indicate a source dead ahead - or dead astern. The homer cannot distinguish this since both signals would arrive at 90 degrees to each antenna.

To determine which direction - turn off course 30 degrees and observe the needle. If it directs you to return to your original heading, the source is ahead.

If the needle points elsewhere - follow it. The indicator needle is affected by radio wave reflections and may bounce around when passing near large metal objects.

Step	Procedure
1	The homer has six channels (6, 12, 13, 14, 16, and 22) in
	addition to the weather channels. Set the channel switch to the
	channel receiving the signal.
2	Request a long count.
3	Turn the squelch control fully counterclockwise.
4	Set volume to a comfortable level.
5	Rotate squelch control to remove speaker noise.
6	Push squelch control IN for homing, OUT for monitoring.
7	Turn the boat in the direction of the pointer until it centers
	itself.
8	Turn 30 degrees to be sure the source is ahead, not aft.
9	Change course as indicated by the needle and proceed to the
	source of the signals, giving due caution to navigation hazards
	that may be between you and your destination.

#### D.16. Light List

Light Lists provide more complete information concerning aids to navigation than can be shown on charts. They are not intended to replace charts for navigation and are published in seven volumes.

Volume	Area of Coverage
Ι	Atlantic Coast, from St. Croix River; Maine to
	Toms River, New Jersey
II	Atlantic Coast, from Toms River, New Jersey to
	Little River Inlet, South Carolina
III	Atlantic Coast, from Little River Inlet, South
	Carolina, to Econfina River, Florida, and the
	Greater Antilles



Volume	Area of Coverage
IV	Gulf of Mexico, from Econfina River, Florida,
	to Rio Grande, Texas
V	Mississippi River System
VI	Pacific Coast and Pacific Islands
VII	Great Lakes

#### **D.17. Tide Tables**

Tide tables give daily predictions of the height of water - at almost any place - at any given time - and are published annually in four volumes. Instructions are provided within the publication on how to use the tables.

Volume	Area of Coverage
I	Europe and West Coast of Africa (including the
	Mediterranean Sea)
II	East Coast of North and South America
	(including Greenland)
III	West Coast of North and South America
	(including the Hawaiian Islands)
IV	Central and Western Pacific Ocean and Indian
	Ocean.

#### D.18. Tidal Current Tables

These tables provide the times of maximum flood and ebb currents, and times of the two slack waters when current direction reverses. They also tell the predicted strength of the current in knots. The time of slack water does not correspond to times of high and low tide. The tide tables cannot be used to predict current predictions. The tables are published in two volumes. Instructions are provided within the publication on how to use the tables.

Volume	Area of Coverage
I	Atlantic Coast of North America
II	Pacific Coast of North America and Asia



#### **D.19.** Coast Pilots

The amount of information that can be printed on a nautical chart is limited by available space and the system of symbols that is used. Additional information is often needed for safe and convenient navigation. Such information is published in the Coast Pilot. These are printed in book form covering the coastline and the Great Lakes in nine separate volumes.

Each Coast Pilot contains sailing directions between points in its respective area, including recommended courses and distances. Channels with their controlling depths and all dangers and obstructions are fully described. Harbors and anchorages are listed with information on those points at which facilities are available for boat supplies and marine repairs. Information on canals, bridges, docks, and more, is included.

Volume	Area of Coverage
	Atlantic Coast
No. 1	Eastport to Cape Cod
No. 2	Cape Cod to Sandy Hook
No. 3	Sandy Hook to Cape Henry
No. 4	Cape Henry to Key West
No. 5	Gulf of Mexico, Puerto Rico, and Virgin Islands
	Great Lakes
No. 6	Great Lakes and connecting waterways
	Pacific Coast
No. 7	California, Oregon, Washington, and Hawaii
	Alaska
No. 8	Dixon Strait to Cape Spencer
No. 9	Cape Spencer to Beaufort Sea

# **D.20.** Navigation Rules (COLREGS)

The Rules of the Road set forth regulations of navigational waters. The Rules of the Road are covered in COMDTINST M16672.2 (series).



### Distance, Speed, and Time

#### D.21. General

Distance, speed, and time are critical elements in navigational calculations. Each has its own importance and use in piloting. And all three are closely associated in the way they are calculated. In planning the sortie or while underway, the typical navigation problem will involve calculating one of these elements based on the value of the other two elements.

# D.22. Expressing distance, speed, and time

Units of measurement are: :

- distance in nautical miles (NM) except statute miles on the western rivers,
- speed in knots, and
- time in minutes.

In calculations and answers, express:

- distance to the nearest tenth of a nautical mile,
- speed to the nearest tenth of a knot, and
- time to the nearest minute.

#### D.23. Formulas

There are three basic equations for distance (D), speed (S), and time (T). Actually, they are the same equation rewritten to calculate each specific element. In each case when two elements are known, they are used to find the third which is unknown. The equations are:

- $D = S \times T/60$
- S = 60D/T
- T = 60D/S

In the equation, 60 is for 60 minutes in an hour.

The following examples show how these equations work:



#### Example # 1:

If your boat is traveling at 10 knots, how far will you travel in 20 minutes? Solve for distance (D).

Step	Procedure
1	$D = S \times T/60$
2	$D = 10 \times 20/60$
3	D = 200/60
	D = 3.3 nautical miles (NM)

#### **Example # 2:**

At a speed of 10 knots, it took the boat 3 hours and 45 minutes to go from your station to the shipping channel. What is the distance to the shipping channel?

Step	Procedure
1	Convert the hours to minutes for solving this equation. First,
	multiply the 3 hours by 60 (60 minutes in an hour), add the
	remaining 45 minutes, that is:
	$3 \times 60 + 45 = 225 \text{ minutes}.$
2	Write the equation.
	$D = S \times T/60$
3	Substitute information for the appropriate letter and calculate
	the distance.
	D = 10  knots  X 225  minutes/60
4	D = 2250/60
	D = 37.5  NM (nearest tenth)

#### **Example # 3:**

Your boat has traveled 12 NM in 40 minutes. What is your speed (S)?

Step	Procedure
1	S = 60D/T
2	S = 60  x 12/40
3	S = 720/40
	S = 18  knots

#### **Example # 4:**

Also, when distance and time are known, speed can be calculated. Your departure time is 2030, the distance to your destination is 30 NM. Calculate the speed you must maintain to arrive at 2400.



Step	Procedure	
1	Calculate the time interval between 2030 and 2400. To	
	determine the time interval, convert time to hours and minutes	
	and then subtract.	
	23 hours 60 minutes (2400)	
	- 20 hours 30 minutes (2030)	
	3 hours 30 minutes	
2	Distance - Speed - Time equations are computed in minutes.	
	Convert the 3 hours to minutes, add the remaining 30 minutes.	
	3 x 60 = 180 minutes	
	<u>+ 30</u>	
	210	
3	Write the equation.	
	S = 60D/T	
4	Substitute information for the appropriate letter and calculate	
	your speed.	
	S = 60D/T	
	$S = 60 \times 30$ nautical miles/210 minutes	
5	S = 1800/210	
	S = 8.6  knots	

### Example # 5:

You are cruising at 15 knots and have 12 NM more before reaching your destination. Determine how much longer before you arrive at your destination.

Step	Procedure	
1	1. $T = 60D/S$	
	D= 12 NM	
	S = 15  knots	
2	$T = 60 \times 12/15$	
3	T = 720/15	
4	T = 48  minutes	



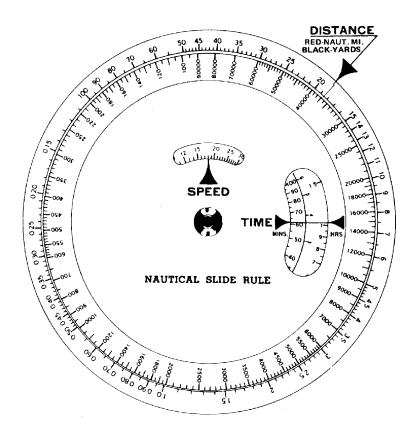
### D.24. Nautical slide rule

The nautical slide rule was designed to solve speed, time and distance problems. Use of the slide rule provides greater speed and less chance of error than multiplication and division. There are several types of nautical slide rules but all work on the same basic principle.

The nautical slide rule has three scales that can rotate. The scales are clearly labeled for:

- speed
- time, and
- distance.

By setting any two of the values on their opposite scales, the third is read from the appropriate index. (See Figure 14-25 which is set for the approximate values of SPEED of 18.2 knots, TIME of 62 minutes and DISTANCE of 18.4 NM or 36,800 yards).



Nautical Slide Rule Figure 14-25



### **Fuel Consumption**

#### D.25. General

In calculating solutions for navigation problems it is also important to know how much fuel your boat will consume - this is to ensure that you will have enough fuel on board to complete the sortie. There must be enough fuel to arrive on scene, conduct operations, and then return to base (or a refueling site).

## **D.26.** Calculating fuel consumption

Calculating fuel consumption may be done by the following procedures:

Step	Procedure
1	Ensure fuel tank(s) are topped off.
2	Measure and record total gallons in fuel tank(s).
3	Start engine(s).
4	Record time engine(s) were started.
5	Set desired RPMs for engine(s).
6	Record set RPMs.
7	Maintain set RPMs.
8	Stop engine(s) at a specified time (usually one hour).
9	Record time.
10	Measure and record total gallons of fuel in tank(s).
11	Subtract total gallons in tank(s) after running one (1) hour from
	total gallons recorded on boat at beginning of underway period.
12	Record the difference.
13	Measure the distance traveled and record.
14	Compute boat speed and record.
15	Apply the equation: Time (T) times gallons per hour (GPH)
	equals total fuel consumption (TFC); or
	$T \times GPH = TFC.$
16	Calculate TFC for other selected RPM settings.
	(Change RPM setting and repeat Steps 6 through 15.)



### **Terms Used In Piloting**

#### D.27. General

The following terms and their definitions are the most commonly used in the practice of piloting.

Term	Abbreviation	Description
Bearing	B, Brg.	Bearing: The horizontal direction of one terrestrial (earth bound) point from another (the direction in which an object lies from you) is its bearing, expressed as the angular distance (degrees) from a reference direction (a direction used as a basis for comparison of other direction). A bearing is usually measured clockwise from 000° through 360° at the reference direction - true north, magnetic north or compass north.
Course	С	The intended horizontal direction of travel (the direction you intend to go), expressed as angular distance from a reference direction clockwise through 360°. For marine navigation, the term applies to the direction to be steered.
Heading	Hdg.	The actual direction the boat's bow is pointing at any given time.
Course line		Line drawn on a chart going in the direction of a course.
Current sailing		Current sailing is a method of allowing for current in determining the course made good, or of determining the effect of a current on the direction or motion of a boat.
Dead reckoning	DR	Dead reckoning is the determination of approximate position by advancing a previous position for course and distance only, without regard to other factors, such as, wind, sea conditions and current.
Dead reckoning plot		A DR plot is the plot of the movements of a boat as determined by dead reckoning.
Position		Position refers to the actual geographic location of a boat. It may be expressed as coordinates of latitude and longitude or as the bearing and distance from an object whose position is known.



Term	Abbreviation	Description
DR position		A DR position is a position determined by plotting a
		single or a series of consecutive course lines using only
		the direction (course) and distance from the last fix,
		without consideration of current, wind, or other external
		forces on a boat.
Estimated position	EP	A DR position modified by additional information which
		in itself is insufficient to establish a fix.
Estimated time of	ETA	The ETA is the best estimate of predicted arrival time at
arrival		a known destination.
Fix		A fix is a position determined from terrestrial, electronic
		or celestial data at a given time with a high degree of
		accuracy.
Line of position	LOP	A line of bearing to a known object which a vessel is
		presumed to be.
Coast piloting		Coast Piloting refers to directing the movements of a
		boat near a coast.
Range		There are two types of ranges used in piloting:
		1. Two or more fixed objects in line. Such
		objects are said to be in range.
		2. Distance in a single direction or along a
		great circle. Distance ranges are measured by means of
		radar or visually with a sextant.
Running fix	R Fix	A running fix is a position determined by crossing LOPs
		obtained at different times.
Speed	S	The rate of travel of a boat through the water measured
		in knots is the speed. A knot is a unit of speed equal to
		one nautical mile per hour. A nautical mile is 2,000
		yards or one minute of latitude.
		1. Speed of Advance (SOA) is the average speed in
		knots which must be maintained to arrive at a destination
		at any appointed time.
		2. Speed made good: Speed over ground (SOG) is the
		speed of travel of a boat along the track, expressed in
		knots;
		3. The difference between the estimated average speed
		(SOA) and the actual average speed (SOG) is caused by
		external forces acting on the boat (such as wind, current,
		etc.).



Term	Abbreviation	Description
Track	TR	A track is the course followed or intended to be followed
		by a boat. The direction may designated true or
		magnetic.
Set		The direction toward which the current is flowing
		expressed in degrees true.
Drift		The speed of the current usually stated in knots.
Course over	COG/CMG	The resultant direction of movement from one point to
ground/course		another.
made good		



### **Laying the Course**

#### D.28. Procedure

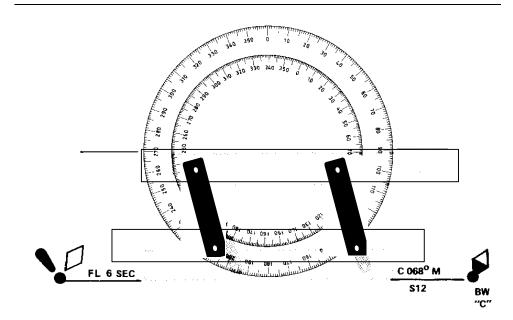
The navigation plot typically includes several course lines to steer from your beginning point to arrival at your destination. The technique for laying each course line is the same and is summarized as follows: (See Figure 14-26)

#### NOTE &

Ensure the rulers do
not slip. If they do,
the original line of
direction will be
lost.

Step	Procedure
1	Draw a straight line from your departure point to the intended
	destination. This is your course line.
2	Lay one edge of your parallel rulers along the course line.
3	Walk the rulers to the nearest compass rose on the chart,
	moving one ruler while holding the other in place.
4	Walk the rulers until one edge intersects the crossed lines at the
	center of the compass rose.
5	Going from the center of the circle in the direction of the
	course line, read the INSIDE degree circle where the ruler's
	edge intersects. This is your magnetic course (M).
6	Write your course along the top of the penciled trackline as
	three digits followed by the letter (M) Magnetic, for example,
	C 068 M.
	Figure 14-26 shows a course of 068° M between two buoys as
	measured by parallel rulers on a chart's compass rose.





**Figure 14-26** 



### **Dead Reckoning (DR)**

#### D.29. General

Dead reckoning (DR) is widely used in navigation. It is the process of determining a boat's approximate position by applying its speed, time and course from its last known position.

# D.30. Key elements of dead reckoning

The key elements of dead reckoning are the course steered and the distance traveled without consideration to current, wind or other external forces.

D.30.a. Course steered

Only courses steered are used to determine a DR. Course for a boat is normally magnetic (M) since it usually does not carry a gyrocompass which gives true (T) direction.

D.30.b. Distance traveled

Distance traveled is obtained by multiplying your speed (in knots) by the time underway (in minutes).

$$D = S \times T/60$$

(On the western rivers, distance is in statute miles.)

#### D.31. Standardized plotting symbols

All lines and points plotted on a chart must be labeled. The symbols commonly used in marine navigation are standardized and summarized as follows:

#### NOTE &

Only standard symbols should be used to make it possible for every crew member to understand the plot.

- Labeling the Fix: The plotter should clearly mark a visual fix with a circle or an electronic fix with a triangle. Clearly label the time of each fix. A visual running fix should be circled, marked "R Fix" and labeled with the time of the second LOP. Maintain the chart neat and uncluttered when labeling fixes.
- **DR position**: A point marked with a semicircle and the time.
- **Estimated position (EP)**: A point marked with a small square and the time.

See Figure 14-27 for examples of the plotting symbols.

# D.32. Labeling a DR plot

The DR plot starts with your last known position (usually a fix). The procedure for labeling a DR plot is given below. (See Figure 14-27)

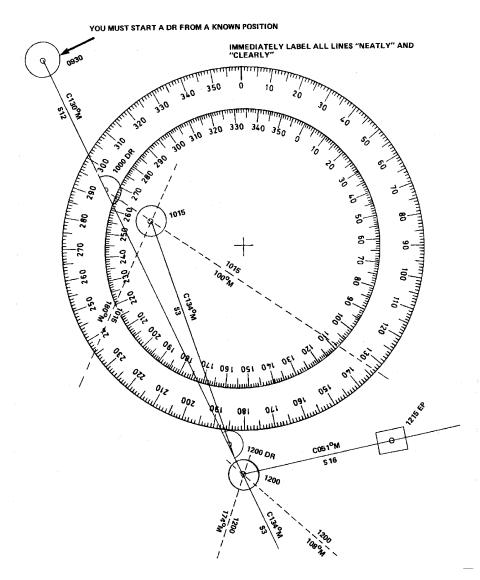
Figure 14-27 shows a DR plot starting in the upper left corner from a



0930 fix. (The compass rose is shown for information purposes and is not always so obvious on the chart.) At 1015 a fix is taken and a new DR plot started. Also, at 1015, the course is adjusted to C 134 M to get to the intended destination at the 1200 DR plot. Then, the 1200 fix is plotted and the new DR plot (C 051 M and S 16) is started.

Step	Procedure	
1	Plot your course line, label it clearly and neatly.	
	• Course: Above the course line place a capital C followed	
	by the ordered course in three digits.	
	• <b>Speed</b> : Below the course line place a capital S followed by	
	the speed	
2	Use standard symbols to label a DR plot:	
	Circle for a fix.	
	Semicircle for a DR position.	
	Square for an estimated position.	
3	Plot a DR position:	
	At least every half hour.	
	At the time of every course change.	
	At the time of every speed change.	
4	Start a new DR plot from each fix or running fix (plot a new	
	course line from the fix).	
5	<b>Time</b> is written as four digits.	





Labeling a DR Plot Figure 14-27

The course can be magnetic (M), true (T) or compass (C) and is always expressed in three digits. If the course is less than 100 degrees, zeros are prefixed to the number, for example, 009°.



### **Basic Elements of Piloting**

#### D.33. General

Direction, distance, and time are the basic elements of piloting. With these elements, an accurate navigation plot can be maintained.

#### **D.34.** Direction

Direction is the relationship of one point to another point (known as the reference point). Direction, referred to as bearing, is measured in degrees from 000 through 360.

# D.34.a. Reference point/ reference direction

The usual reference point is 000°. The relationships between the reference points and reference directions are listed below:

<b>Reference Direction</b>	Reference Point
True (T)	Geographical North Pole
Magnetic (M)	Magnetic North Pole
* Compass (C)	Compass North
* Relative (R)	Boat's Bow

<sup>\*</sup> Not to be plotted on a chart.

#### D.35. Bearings

Bearings are a direction, expressed in degrees from a reference point. Bearings may be, true, magnetic, compass, or relative. You may use all of the above reference directions except relative direction to designate headings or courses. Relative direction, which uses the boat's bow as the reference direction, changes constantly.

In boat navigation, you will usually use magnetic courses and bearings since true bearings are obtained from gyro compasses which are not normally found on boats.

# D.35.a. Obtaining bearings

Bearings are obtained primarily by using your magnetic compass (compass bearings) or radar (relative bearings). Bearings of fixed, known, objects are the most common sources for lines of position (LOPs) in coastal navigation. When using your compass to take bearings, sight the object across the compass.



## **D.36.** Compass bearings

In the section on compass and compass error, it was discussed how to convert from a compass course to magnetic and true courses by correcting the compass. A compass bearing must be corrected before it can be plotted.

NOTE &

DEVIATION always depends upon your boat's heading.

The BEARING (compass or relative) of any object is not your course.

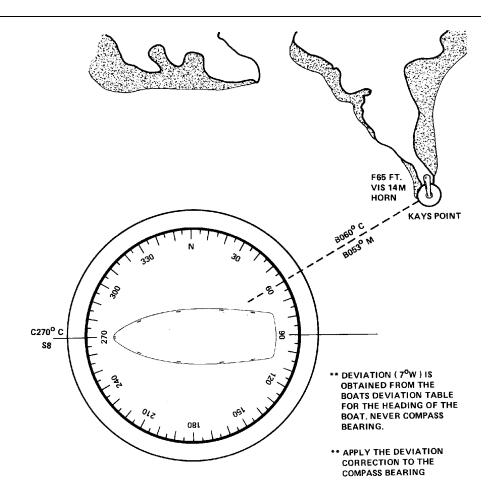
Enter the deviation table with the COMPASS HEADING you are steering to obtain proper deviation.

D.36.a. Obtaining compass bearings

You are on a heading of 270° M. You observe that the compass bearing to Kays Pt. Light is 060°. Deviation from the deviation table on the boat's heading of 270° M is 7°W. Obtain magnetic bearing of Kays Pt. Light. (See Figure 14-28)

Step	Procedure
1	Correct your compass bearing of 60° magnetic. Write down
	the correction formula in a vertical line.
	$C = 060^{\circ}$ compass bearing of light.
	$D = 7^{\circ}W$ (+E, -W) from deviation table for boat's heading
	M = What is the magnetic bearing of the light?
2	Compute information you have opposite appropriate letter in
	STEP 1.
3	Subtract 7°W deviation, the westerly error, from the compass
	bearing (060°) to obtain magnetic bearing (053°).
	$M = 053^{\circ}$





Converting Compass Bearing to Magnetic Figure 14-28

# D.37. Relative bearings

Relative bearing of an object is its direction from the boat's bow at 000 degrees, measured clockwise through 360 degrees.

D.37.a. Converting to magnetic bearings

Relative bearings must be converted to magnetic bearings before they can be plotted. The steps are:

1. Convert your heading to a magnetic course. Based on the boat's heading at the time the bearing was taken, use the deviation table to determine the deviation. (Deviation depends on your boat's heading - not that of the relative bearing.)



- 2. Add the relative bearing.
- 3. If this sum is more than 360 degrees, subtract 360 degrees to obtain the magnetic bearing.

Three examples follow to demonstrate these steps.

#### Example # 1:

You are on a heading of 150°. You observed that the relative bearing to a standpipe was 125 degrees relative. Deviation (from the boat's deviation table) on the boat's heading is 4°E. Obtain the magnetic bearing of the standpipe.

Step	Procedure
1	Correct your heading of 150° to magnetic. Write down the
	correction formula in a vertical line.
	$C = 150^{\circ}$
	$D = 4^{\circ}E  (+E, -W)$
	M = 154 degrees
	V = Not applicable in this problem
	T = Not applicable in this problem
2	Compute information you have opposite appropriate letter in
	STEP 1.
3	Add the easterly error, 4°E deviation from the compass heading
	to obtain magnetic heading (154°).
4	Add the observed relative bearing (125 degrees) and the
	magnetic heading (154°) to obtain magnetic bearing (279°M) of
	the standpipe.

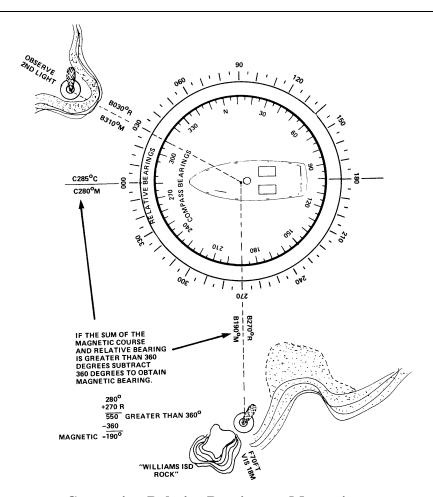
#### **Example # 2:**

Your boat is on a heading of 285°. You observed that the relative bearing to Williams ISD Rock Light is 270 degrees relative. You also observed that the relative bearing to another light is 030 degrees relative. Deviation from the boats deviation table on the boats heading is 5°W. Obtain magnetic bearing of both lights. (See Figure 14-29)



Step	Procedure
1	Correct your heading of 285 to the magnetic heading. Write
	down the correction formula in a vertical line.
	$C = 285^{\circ}$
	$D = 5^{\circ}W  (+E, -W)$
	$M = 280^{\circ}$
	V = not applicable to this problem
	T = not applicable to this problem
2	Compute information you have opposite appropriate letter in
	STEP No. 1. Subtract the westerly error, 5°W deviation from
	the compass heading (285°) to obtain magnetic heading (280°).
3	Add each of the observed relative bearings (270 degrees
	relative and 030 degrees relative) to the magnetic heading
	(280°) to obtain the magnetic bearings.
	W1LLIAMS ISD ROCK
	280° M
	$\pm 270^{\circ}$ relative bearing
	550 degrees (greater than 360 degrees)
	<u>-360</u>
	190° magnetic bearing
	OTHER LIGHT
	280° M
	$+030^{\circ}$ relative bearing
	310° magnetic bearing





Converting Relative Bearings to Magnetic; Sums Greater than 360 Degrees Figure 14-29

#### **D.38.** Distance

The second basic element in piloting is the special separation of two points measured by the length of a straight line joining the points without reference to direction. In piloting, it is measured in miles or yards. There are two different types of miles used: nautical miles and statute miles.

## D.38.a. Nautical mile

The nautical mile is used for measurement on most navigable waters. One nautical mile is 6076 feet or approximately 2000 yards and is equal mile to one minute of latitude.



D.38.b. Statute mile

The statute mile is used mainly on land, but it is also used in piloting inland bodies of water such as the Mississippi River and its tributaries, the Great Lakes and the Atlantic and Gulf Intracoastal waterways.

D.38.c. Measuring distance

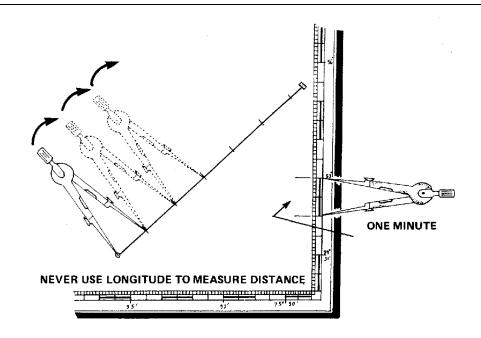
Measure the distance by:

Step	Procedure
1	Place one end of pair of dividers at each end of the distance to
	be measured; being careful not to change the span of the
	dividers.
2	Transfer them to the latitude scale closest to the latitude being
	measured, read the distance in minutes. (See Figure 14-30)
3	When the distance to be measured is greater than the span of
	the dividers, the dividers can be set at a minute or number of
	minutes of latitude from the scale and then "stepped off"
	between the points to be measured.
4	The last span, if not equal to that setting on the dividers, must
	be separately measured. To do this, step the dividers once
	more; closing them to fit the distance.
5	Measure this distance on the scale and add it to the sum of the
	other measurements.
6	The latitude scale nearest the middle of the line to be measured
	should be used.

### NOTE &

The Longitude scale is never used for measuring distance.

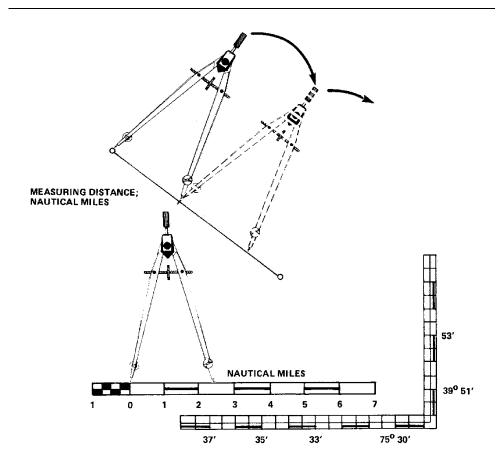




Measuring Distance, Latitude Figure 14-30

To measure short distances on a chart the dividers can be opened to a span of a given distance, then compared to the nautical mile or yard scale on the chart. (See Figure 14-31)





Measuring Distance, Nautical Miles Figure 14-31

#### **D.39.** Time

Time is the third basic element in piloting. Time, distance, and speed are related. Therefore, if any two of the three quantities are known, the third can be found. The basic equations for distance, speed, and time, the speed curve and nautical slide rule and their use have been discussed earlier.



### **Plotting Bearings**

#### D.40. General

A bearing or series of bearings can be observed as compass (C), magnetic (14), true (T), or as a relative bearing (visual or radar). The compass bearing reading usually needs to be converted for plotting and then drawn on the chart as a line of position (LOP).

#### D.41. Parallel

One common method of plotting bearings on a chart is using parallel rulers or a course plotter. Follow the procedures below for plotting the bearing on to the chart.

#### **Example:**

Your boat is on a heading of 192° compass. At 1015 you obtain a bearing of 040 degrees relative on a water tower. Deviation from the boat's deviation table on the boat's heading is 3°W.

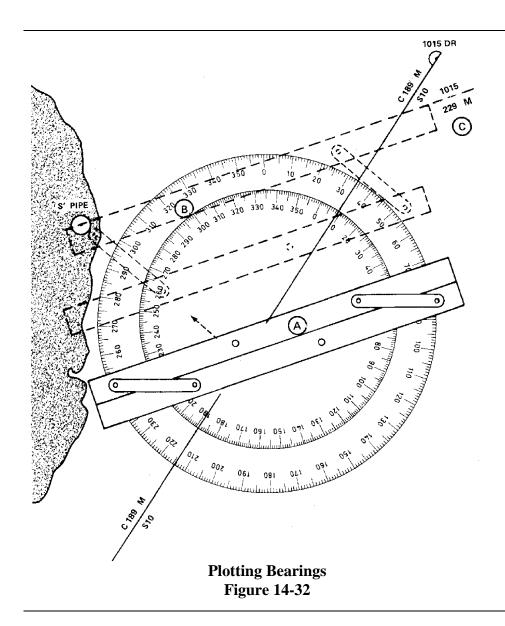
Step	Procedure
1	Correct your compass heading of 192° to the magnetic
	heading.
	Write down the correction formula in a vertical line.
	$C = 192^{\circ}$
	$D = 3W^{\circ}$ (+E, -W when correcting)
	$M = 189^{\circ}$
	V = not applicable to this problem
	T = not applicable to this problem
2	Compute information you have opposite appropriate letter in
	STEP 1. Subtract the westerly error, 3°W deviation from the
	compass heading (192°) to obtain magnetic heading (189°)
3	Add the relative bearing (040 degrees) to the magnetic heading
	(189') to obtain the magnetic bearing (229°); or
	189°- (M)
	$+040^{\circ}$
	229° magnetic bearing
4	Place the parallel rulers with their edge passing through the
	crossed lines at the center of the compass rose and the 229°
	mark on the inner ring (magnetic) of the compass rose. (See
	Figure 14-32)



Step	Procedure
5	Walk the parallel rulers to the dot marking the exact position
	of the water tower.
6	Draw a broken line and intersect your course Line (C 189
	M).
7	Label a segment of line with the time of the bearing along the
	top. The segment is drawn near the course line, not the entire
	length from the water tower.
8	Below the line label the magnetic bearing 229 M.

At 1015 your boat was somewhere along your LOP. A single line of bearing gives you a line of position but you cannot accurately fix your boat's location by a single LOP.







### **Line of Position (LOP)**

#### D.42. General

The position of a boat can be determined by many methods of piloting. The line of position (LOP) is common to all methods of piloting. For example, if you observe a standpipe and a flagstaff in a line, you are somewhere on the line drawn from the standpipe through the flagstaff and towards your boat. This line is called a range or a visual range.

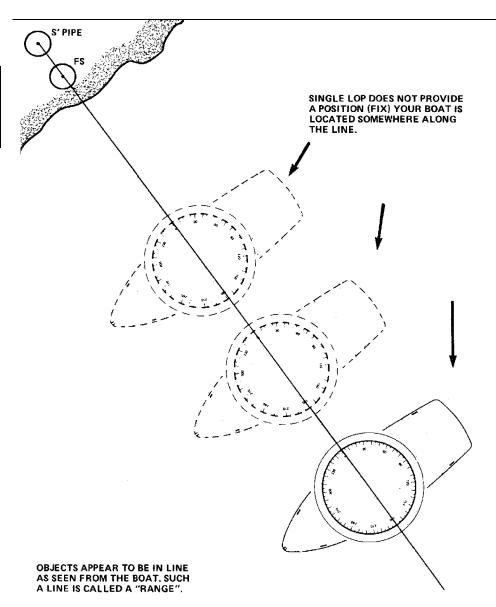
If the bearing is taken on a single object, the line drawn is called a bearing line of position. The observed bearing direction must be corrected to magnetic or true direction and plotted. The compass rose can be used to provide the direction.

A single observation gives an LOP, not a position - you are located somewhere along that LOP. (See Figure 14-33)



### NOTE &

A boat's position is somewhere along the line of position.



Visual Range LOP Figure 14-33

D.43. Selecting objects to obtain a fix

NOTE &

The primary consideration in selecting charted objects to obtain a fix is the angle between the bearings. Also, always attempt to take bearings on object as close as possible to your boat because minor errors in reading are magnified as you increase your distance from the object.

An error of 1 degree at 1 mile will result in an error of 100 feet.



D.43.a. Two lines of position

When you have only two LOPs for a fix, the quality of the fix will be maximum when there is a 90 degree difference in the lines. Serious error in position could result if a difference of less than 60 degrees or more than 120 degrees between the two lines exist. Therefore, two LOPs should intersect at right angles or near right angles wherever possible.

D.43.b Three lines of position

An ideal fix has three or more LOPs intersecting at a single point AND the LOPs have a separation of at least 60 degrees but not more than 120 degrees.

### **D.44.** Obtaining fixes

#### NOTE &

For a fix to be accurate, LOPs must be from simultaneous observation (exact same time). Two or more bearings taken one after the other are considered simultaneous.

A single line of bearing gives an LOP, and your boat is somewhere along that LOP. You cannot accurately fix your position by a single line of position. Two or more intersecting LOPs or radar ranges must be plotted to obtain an accurate fix. The greater the number of lines of position or radar ranges intersecting at the same point, the greater the confidence in the fix. For a fix to be accurate, LOPs must be observed at the same time. However, in navigation you can take two or more bearings, one after the other, and consider them observed at the same time (simultaneous).

D.44.a. Obtaining bearings

Bearings are obtained by visual sightings across a compass, hand held bearing compass, relative bearings (Dumb Compass) or by radar. Then the direction to the object sighted on is recorded, converted to magnetic or true direction, and plotted.

D.44.b. Using cross bearings

When using cross bearings the fix is obtained by taking bearings on two well defined objects and plotting the observed bearings on the chart. A more accurate fix can be obtained by taking a third bearing on a well defined object. The three lines of position should form a single point or a small triangle. Your boat's position is then considered to be on the point or in the center of the small triangle.



A large triangle is an indication than an inaccurate bearing was taken, double check your measurements.

### **CAUTION!**

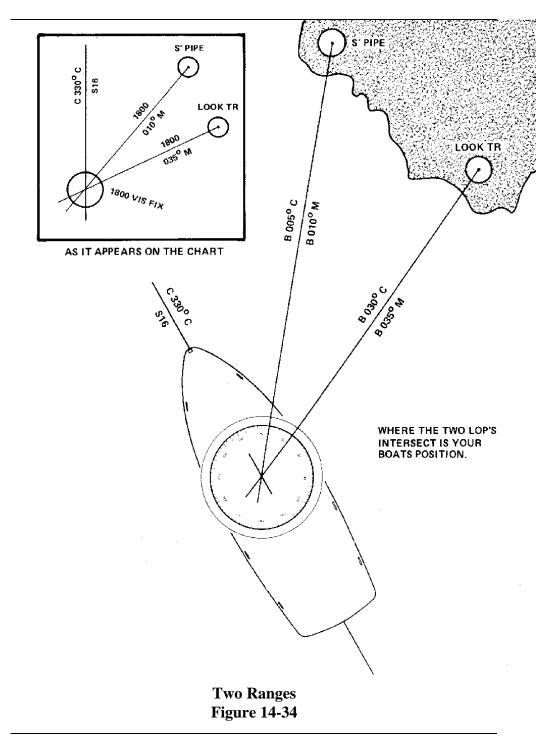
Do not use the hand held bearing compass on a steel boat, you cannot determine deviation accurately. Each change in position on deck results in an undetermined amount of deviation.

### **Example:**

On a compass heading of 330°, you sight a lookout tower and a standpipe and decide to take a fix. You observe the lookout tower to bear 030° (compass) with the standpipe bearing 005° (compass). Deviation from the deviation table, on the boat's compass heading (330° C), is 5°E. Plot your fix. (See Figure 14-34)

Step	Pro	cedure
1	Correct your compass bearing (030°) and (005°) to magnetic bearings. Write down the correction formula in a vertical line.	
	Lookout Tower	Standpipe
	$C = 030^{\circ}$	C = 005°
	$D = 5^{\circ}E (+E, -W)$	$D = 5^{\circ}E (+E, -W)$
	$M = 035^{\circ}$	$M = 010^{\circ}$
	V = not applicable	V = not applicable
	T = not applicable	T = not applicable
2	Compute information you	
	appropriate letter in STEP	No. 1. Add the easterly
	error 5°E deviation to the	1
	005° to obtain magnetic be	
3	Plot the two magnetic bearings. The prudent sailor will	
		y of this fix is doubtful due to
		ings being considerably less
	than the desired 60-120 de	grees.







#### D.44.c. Ranges

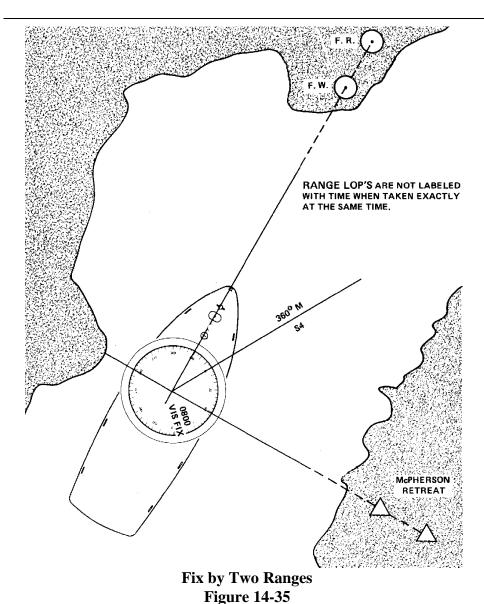
When two charted objects are in range, as seen from a boat, the boat is located somewhere on a straight line through these objects. Frequently a range will mark the center of a channel. The boat is steered so as to keep the range markers in line.

Ranges may be established navigational aids or natural ranges such as a church steeple and a water tower. When entering or leaving a harbor, it is often possible to fix your position by means of ranges.

#### **Example:**

You are steering on a range. While steering on this range (keeping the bow lined up with the two range marks), you note the time is 0800 when two charted objects (for example, a water tank and smoke stack) line up on the starboard side. The boat's position is at the intersection of the lines drawn through each set of ranges. (See Figure 14-35) After having observed two sets of ranges which determined a fix, you come to a magnetic course of 330° M to stay in safe water.





D.44.d Running fix (R FIX)

Often it is impossible to obtain two bearing observations within close enough interval time to be considered simultaneous. A running fix (R Fix) can be obtained by using two lines of position acquired at different times. It is determined by advancing an earlier LOP by using dead reckoning calculations of the boats direction and distance traveled during an interval. (See Figure 14-36)

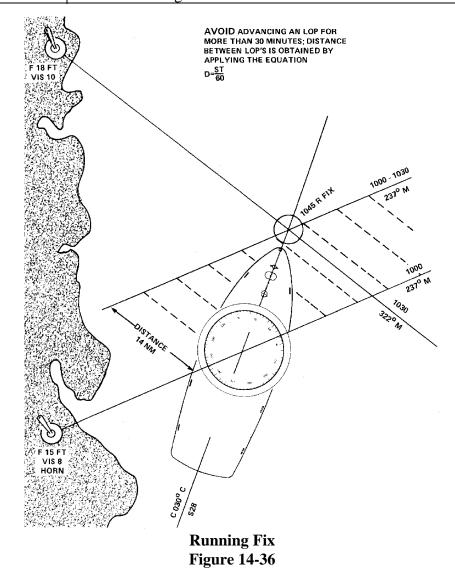


Plot a running fix by the following the steps:

### NOTE &

The shorter the time interval between LOPs, the more accurate the running fix.

Step	Procedure
1	Plot the first LOP. Plot the second LOP.
2	Advance the first LOP along your DR plot to the time of second LOP. (The first LOP is advanced by moving it parallel to itself, forward along the course line for the distance the boat will have traveled to the time of the second bearing.)
3	Where the two LOPs intersect is your running fix.
4	Avoid advancing a LOP for more than 30 minutes.





#### **Example:**

At 1000 you observed a compass bearing of 240° to a light. There were no other well defined objects from which to obtain a bearing. Since plotting the first LOP you have run at 28 knots on a compass course of  $030^{\circ}$  C

At 1030 you observe a second compass bearing of 325° to the light. Plot this as a second LOP and advance your first LOP. The position where they cross is your running fix.

Step	Procedure
1	Obtain the time interval and the distance your boat traveled
	since your 1000 LOP.
	(A Nautical Slide Rule may be used)
	10 hours 30 minutes
	<u>-10 hours 00 minutes</u>
	30m - time interval
	Apply the equation for Distance (Nautical slide Rule may be
	used).
	$D = S \times T/60$
	$D = 28 \times 30/60$
	D = 840/60
	D = 14 nautical miles
2	Using your dividers measure the distance (14 NM) off of the
	latitude or nautical mile scale along the course line in the
	direction traveled.
3	Advance your first LOP, ensuring it is moved parallel to
	itself, forward along the course line for the distance traveled
	(14 NM). Draw the LOP labeling the new line (1000-1030)
	to indicate that it is an advanced LOP.
4	Correct the compass bearing of the second light (325° C) to
	obtain the magnetic bearing (322° M)
5	Plot the bearing. You now have established a running fix by
	advancing an LOP.

D.43.e. Danger bearings

Danger bearings are used to keep a boat clear of a hazardous area in the vicinity of your track. Danger bearings are the maximum or minimum bearing of a point used for safe passage. They indicate a charted object whose bearing will place you outside that hazardous area. Examples of



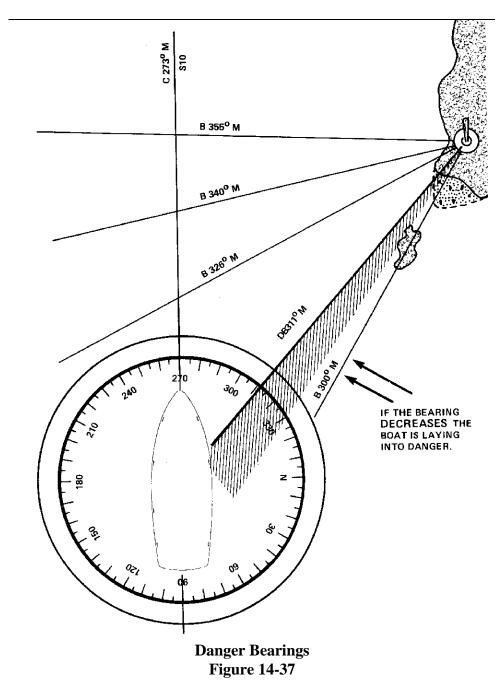
such dangers are submerged rocks, reefs, wrecks and shoals. A danger area must be established in relation to two fixed objects, one of which is the danger area. The other object must be selected to satisfy three conditions:

- visible to the eye
- indicated on the chart; and
- bearing from the danger area should be in the same general direction as the course of the boat as it proceeded past the area.

Plot a danger bearing with the steps below: (See Figure 14-37).

Step	Procedure
1	On a chart, draw a line from the object selected (the leading
	object) to a point tangent to the danger area closest to where
	you intend to pass. The measured direction of the line from
	the danger area to the leading object is the danger bearing.
	Figure 14-37 indicates that 311° M is a danger bearing.
2	Label the danger bearing with the abbreviation 'DB' followed
	by the direction (DB 311 M). Frequent visual bearings
	should be taken. If the bearings are greater than the danger
	bearing, your boat is in safe water.





When a bearing is observed to be less than the danger bearing, such as  $300^{\circ}$  M, your boat is standing into danger. Danger bearings should have a series of shot lines drawn on the danger side for easy identification as shown in figure 14-37.



The label DB may be proceeded by the letters NMT (not more than) or NLT (not less than) as appropriate.

The coxswain should ensure that all crew members are aware of where the danger lies. That is, whether the danger includes all degrees less than the danger bearing or all the degrees greater than the danger bearing.



### Set and Drift (Current Sailing)

#### D.45. General

Current sailing is the method of computing course and speed through the water, considering the effects of current so that, upon arrival at your destination, the intended course (track) and the actual course made good are the same. The difference in position between a DR position and a fix taken at the corresponding time is due to various external forces acting on the boat. These forces are usually accounted for as set and drift.

#### D.46. Definition

**Set** is the direction of these forces and includes factors such as wind, current and sea condition. Set is expressed in degrees. 'Set 240° magnetic' means that the boat is being pushed towards 240° magnetic.

**Drift** is the strength of the set and is expressed in knots. 'Drift 1.5 knots' means that the boat is being pushed in a given direction (set) at a speed of 1.5 knots.

### D.47. Making allowances

In working problems involving set and drift you must allow for their effect upon your boat. This can be accomplished by comparing actual fix position information with your DR track and determining the difference. However, conditions do not always allow for this. Also, this can only be done after some portion of your voyage has already occurred.

### D.48. Tidal Current Charts

Tidal Current Charts which are available for certain bodies of water such as Boston Harbor or San Francisco Bay. They indicate graphically the direction and velocity of tidal currents for specific times with respect to the state of the current predictions for major reference stations. These charts make it possible to visualize how currents act in passages and channels throughout the 12-hour cycle. By referring to the current charts you can plan a passage which is made quicker by either taking advantage of a favorable current or picking a track which reduces the effect of a head current.



### D.49. Tidal Current Tables

Tidal Current Tables are used to predict tidal currents. Examples of how to apply predicted currents are found in the back of the publication. This allows you to apply the corrections well in advance so that you may avoid the dangers along the way and safely arrive at your destination. This method involves the use of a vector diagram called a current triangle.

NOTE &

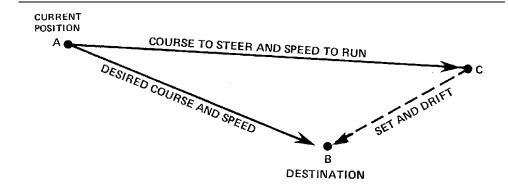
The tidal current directions are shown in degrees true and must be converted to magnetic before plotting the set and drift problem.

#### D.50. Current

The current triangle is a vector diagram from which you can find the course and speed your boat will make good when running a given course at a given speed. (See Figure 14-38) It can also be used to determine the course to steer and the speed necessary to remain on your intended track. You may obtain this information by using the chart's compass rose for constructing a current triangle to provide a graphic solution.

- The first line (AB) on a current triangle indicates your boat's intended direction and the distance to travel in a given period of time. The length of this line represents your boat's speed in knots.
- The second line, (CB) laid down to the destination end of the intended direction (the first line), shows the set (direction) of the current. The length of this line represents the drift (speed) of the current in knots.
- The third line (AC) provides the resulting corrected course to steer and the speed of advance to arrive safely at your destination. If any two sides of the triangle are known the third side can be obtained by measurement.





- A: YOUR BOAT POSITION
- **B: DESTINATION**
- AB: YOUR BOATS INTENDED TRACK (TR) AND SPEED OF ADVANCE (SOA)
- BC: THE CURRENTS DIRECTION (SET) AND ITS SPEED
- AC: YOUR BOATS CORRECTED COURSE AND SPEED

# Current Triangle Figure 14-38

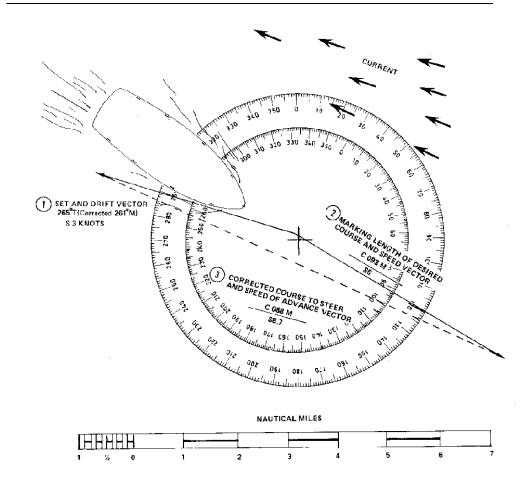


### **Example:**

The intended track to your destination is 093° magnetic (093M), your speed is 5 knots, the Tidal Current Table for your operating area indicates that the current will be setting your boat 265° true (265T), drift (speed) 3 knots. The local variation is 4 degrees (W). Obtain the corrected course to steer and speed of advance (SOA) to allow for set and drift. (See Figure 14-39, the nautical miles scale is provided as an example for measuring "units" of length.)

Step	Procedure
1	Lay out your chart. Think of the center of the compass rose
	as your departure point. Draw your boat's intended track
	(093° M) from the center of the compass rose: Make this line
	'5 units' in length to represent '5 nautical miles' from the
	center of the compass rose. Put a small arrowhead at this
	point. This is your desired course and speed vector.
2	Draw your line for the set and drift of the current from the
	center of the compass rose towards 261° magnetic (265°T -
	$4^{\circ}W \text{ (variation)} = 261^{\circ} \text{ M}$ ).
	Set in the Tidal Current Tables is given in degrees true and
	must be converted to degrees magnetic to be used. Make this
	line 3 units long putting an arrowhead at the outer end. This
	is your set and drift vector.
3	Draw a straight line to connect the arrowheads of the desired
	course and speed vector and the set and drift vector. This
	line is your corrected course to steer and speed of advance.
4	Measure the length of this line to obtain the speed (8.7 knots)
	from the nautical miles scale.
5	Advance the line to the center of the compass rose and read
	the corrected magnetic course to steer (088° M) from the
	inner circle of the compass rose.

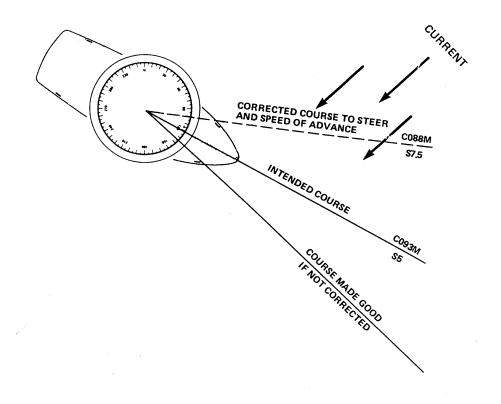




Plotting Set and Drift to Set Course to Steer Figure 14-39

Using the same figures as shown in the above example, Figure 14-40 shows what the effect would be if you do not correct for set and drift by using a current triangle. (See Figure 14-40)





Compensating for Set and Drift Figure 14-40



### Radar

#### D.51. General

Radar is an aid in navigation. It is not the primary means of navigation. Boat navigation using radar in limited visibility depends on the coxswain's experience with radar operation. It also depends on the coxswain's knowledge of the local operating area and is not a substitute for an alert visual lookout.

# D.52. Basic principle

Radar radiates radio waves from its antenna to create an image that can give direction and distance to an object. Nearby objects (contacts) reflect the radio waves back and appear on the radar indicator as images (echoes). On many marine radars, the indicator is called the plan position indicator (PPI).

#### D.53. Advantages

Advantages of radar include:

- Use at night and low visibility conditions.
- Obtain a fix by distance ranges to two or more charted objects.
   An estimated position can be obtained from a range and a bearing to a single charted object.
- Rapid fixes.
- Fixes may be available at greater distances from land than by visual bearings.
- Assistance in preventing collisions.

### D.54. Disadvantages

The disadvantages of radar include:

- Mechanical and electrical failure.
- Minimum and maximum range limitations.

# D.54.a. Minimum range

The minimum range is primarily established by the radio wave pulse length and recovery time. It depends on several factors such as excessive sea return, moisture in the air, other obstructions and the limiting features of the equipment itself. The minimum range varies but is usually 20 to 50 yards from the boat.



### D.54.b. Maximum range

Maximum range is determined by transmitter power and receiver sensitivity. However, these radio waves are line of sight (travel in a straight line) and do not follow the curvature of the earth. Therefore, anything below the horizon will usually not be detected.

### D.54.c. Operational range

The useful operational range of a radar on a boat is limited mainly by the height of the antenna above the water.

### D.55. Reading the radar indicator

Interpreting the information presented on the indicator takes training and practice. The radar indicator should be viewed I total darkness, if possible, for accurate viewing of all echoes. Also, charts do not always give information necessary for identification of radar echoes, and distance ranges require distinct features.

It may be difficult to detect smaller objects (e.g., boats and buoys) in conditions such as:

- heavy seas;
- near the shore; or
- if the object is made of nonmetallic materials.

### D.56. Operating controls

Different radar sets have different locations of their controls, but they are basically standardized on what function is to be controlled. The boat crew should become familiar with the operation of the radar by studying its operating manual and through the unit training program.

# D.57. Reading and interpolating radar images

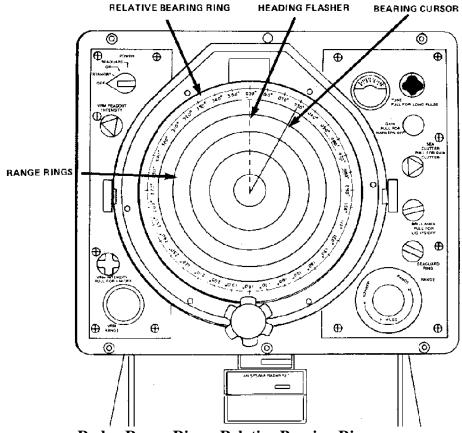
The plan position indicator (PPI) is the face or screen of the CRT (Cathode Ray Tube) which displays a bright straight radial line (tracer sweep) extending outward from the center of a radar screen. It represents the radar beam rotating with the antenna. It reflects images on the screen as patches of light (echoes).

In viewing any radar indicator, the direction in which the boat's heading flasher is pointing can be described as up the indicator. The reciprocal of it is a direction opposite to the heading flasher, or down the indicator. A contact moving at right angles to the heading flasher anywhere on the indicator would be across the indicator.



The center of the radar screen represents the position of your boat. The indicator provides relative bearings of a target and presents a map-like representation of the area around the boat. The direction of a target is represented by the direction of its echo from the center, and the target's range is represented by its distance from the center. (See Figure 14-41).

The cursor is a movable reference and is controlled by the radar cursor control. The cursor is used to obtain the relative bearings of a target on the indicator.



Radar Range Rings, Relative Bearing Ring, Heading Flasher and Bearing Cursor Figure 14-41



### D.57.a. Radar bearings

#### NOTE &

Like visual observations, relative bearing measurements by radar must be converted to magnetic bearing prior to plotting them on the chart.

Radar bearings are measured relative the same as you would in visual bearings with 000 degrees relative being dead ahead. (See Figure 14-41) In viewing any radar indicator, the dot in the center indicates your boat's position. The line from the center dot to the outer edge of the indicator is called the heading flasher and indicates the direction your boat is heading.

To obtain target relative bearings, adjust cursor control until the cursor line crosses the target. The radar bearing is read from where the cursor line crosses the bearing ring.

## D.57.b. Target range

Many radars have a variable range marker. You dial the marker out to the inner edge of the contact on the screen and read the range directly.

Other radars may have distance rings. If the contact is not on a ring, you would estimate (interpolate) the distance by its position between the rings.

#### **Example:**

The radar is on the range scale of 2 nautical miles, and has 4 range rings. Range information is desired for a target appearing halfway between the third and fourth rings.

- 1. Range rings on the two mile scale are 1/2 mile or 1000 yards apart (4 rings for 2 miles means each ring equals 1/4 of the total range of 2 miles).
- 2. Calculate range as  $1000 + 1000 + 1000 + 1/2 \times 1000$  or 3500 yards.

### D.58. Radar contacts

Even with considerable training you may not always find it easy to interpret a radar echo properly. Only through frequent use and experience will you be able to become proficient in the interpretation of images on the radar screen.

Knowledge of the radar picture in your area is obtained by using the radar during good visibility and will eliminate most doubts when radar navigating at night and during adverse weather. Images on a radar screen differ from what is seen visually by the naked eye. This is because some contacts reflect radio waves (radar beams) better than others.



### D.58.a. Common radar contacts

A list of common radar contacts and reflection quality follows:

Contact	Integrity
Reefs, shoals, and wrecks	May be detected at short to moderate ranges, if breakers are present and are high enough to return echoes. These echoes usually appear as cluttered blips.
Sandy spits, mud flats and sandy beaches	Return the poorest and weakest echoes. The reflection, in most cases, will come from a higher point of land from the true shoreline such as bluffs or cliffs in back of the low beach. False shorelines may appear because of a pier, several boats in the area, or heavy surf over a shoal.
Isolated rocks or islands off shore	Usually return clear and sharp echoes providing excellent position information.
Large buoys	May be detected at medium range with a strong echo; small buoys sometimes give the appearance of surf echoes. Buoys equipped with radar reflectors will appear out of proportion to their actual size.
Piers, bridges and jetties	Provide strong echoes at shorter ranges.
Rain showers, hail and snow	Will also be detected by radar and can warn you of foul weather moving into your area.  Bad weather appears on the screen as random streaks known as 'clutter'.

#### D.59. Radar fixes

### NOTE &

If a visual bearing is available it is more reliable than one obtained by radar.

Radar navigation provides a means for establishing position during periods of low visibility when other methods may not be available. A single prominent object can provide a radar bearing and range for a fix, or a combination of radar bearings and ranges may be used. Whenever possible more than one object should be used. Radar fixes are plotted in the same manner as visual fixes.



### **Example:**

On a compass heading of  $300^\circ$ , you observe a radar contact (image) bearing 150 degrees relative. Deviation, from the deviation table, for the boat's compass heading ( $300^\circ$  C) is 3'E.

Obtain the magnetic bearing of the contact.

Step	Procedure
1	Correct you compass heading of 300 degrees to magnetic
	heading.
	Write down the correction formula in a vertical line.
	$C = 300^{\circ}$
	$D = 3^{\circ} E (+E, -W \text{ when correcting})$
	$M = 303^{\circ} M$
	V = not applicable in this problem
	T = not applicable in this problem
2	Compute information you have opposite appropriate letter in
	STEP No. 1. Add the easterly error 3°E deviation to the
	compass heading (300° C) to obtain the magnetic course of
	303° M).
3	Add the radar relative bearing (150 degrees relative) to the
	magnetic heading (303° M) to obtain magnetic bearing of the
	radar contact (093° M).
	303°
	<u>+150</u> °
	453° degrees (greater than 360°)
	4520
	453°
	+360°
	093° M bearing of contact

D.58.a. Range rings

Radar range rings show up as circles of light on the screen to assist in rings estimating distance. Major range scales are indicated in miles and are then subdivided into range rings. Typical range scales for a boat radar are ½, 1, 2, 4, 8, and 16 nautical miles (NM). Typical number of range rings for a particular range scale are shown in the table below.



Scale/Miles	Rings	NM Per Ring
1/2	1	1/2
1	2	1/2
2	4	1/2
4	4	1
8	4	2
16	4	4

D.59.b. Lines of position

Radar lines of position (LOPs) may be combined to obtain fixes. Typical combinations include two or more bearings; a bearing with distance range measurement to the same or another object; two or more distance ranges. Radar LOPs may also be combined with visual LOPs.

Care should be exercised when using radar bearing information only since radar bearings are not as precise as visual bearings. A fix obtained by any radar bearing or by distance measurement is plotted on the chart with a dot enclosed by a circle to indicate the fix and label with time followed by 'RAD FIX', such as, 1015 RAD FIX.

D.59.c. Distance measurements example

At 0215, you are on a course of 303' (303' M). Your radar range scale is on 16 miles. You observe two radar contacts (land or charted landmark). The first has a bearing of 330 degrees relative at 12 NM. This target is on the third range circle. The second target is bearing 035 degrees relative at 8NM. This target is on the second range circle. Obtain a distance measurement fix. (See Figure 14-42)

NOTE &

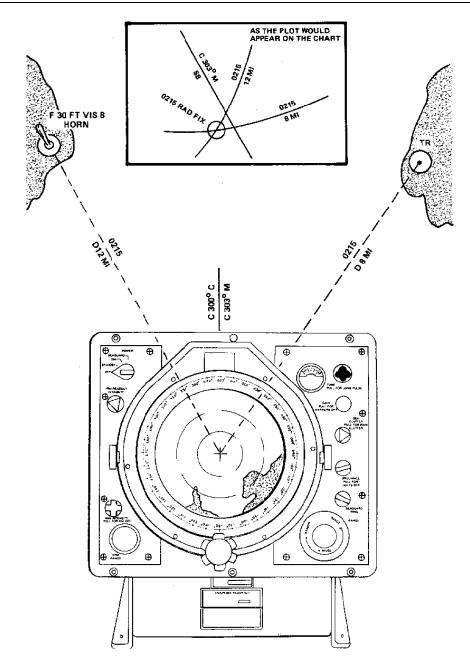
Radar ranges are usually measured from prominent land features such as cliffs or rocks. However, landmarks such as lighthouses and towers often show up at a distance when low land features do not.

Step	Procedure
1	Locate the objects on the chart.
2	Spread the span of your drawing compass to a distance of 12 NM (distance of first target), using the latitude or nautical mile scale on the chart.



Step	Procedure
3	Without changing the span of the drawing compass, place the point on the exact position of the object and strike an arc towards your DR track, plotting the distance.
4	Repeat the above steps for the second object (distance of 8 NM). Where the arcs intersect is your fix (position). Label the fix with time and 'RAD FIX' (0215 RAD FIX).

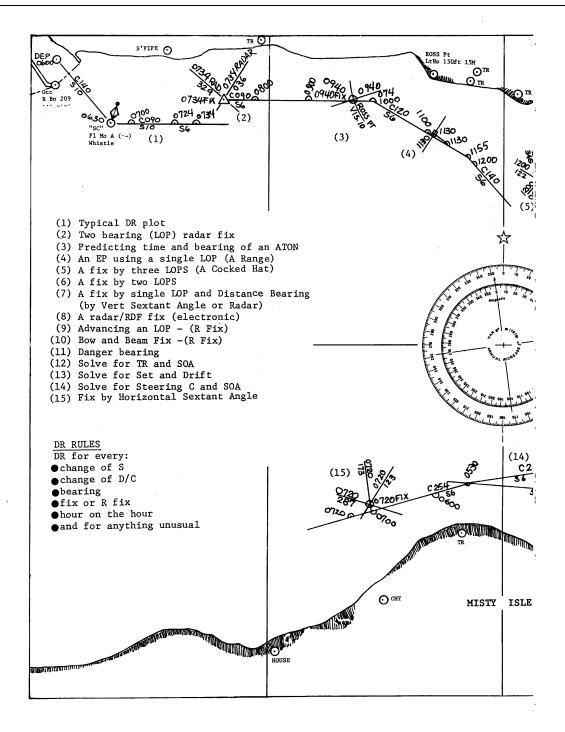




Obtaining a Radar Fix Using Two Distance Measurements Figure 14-42

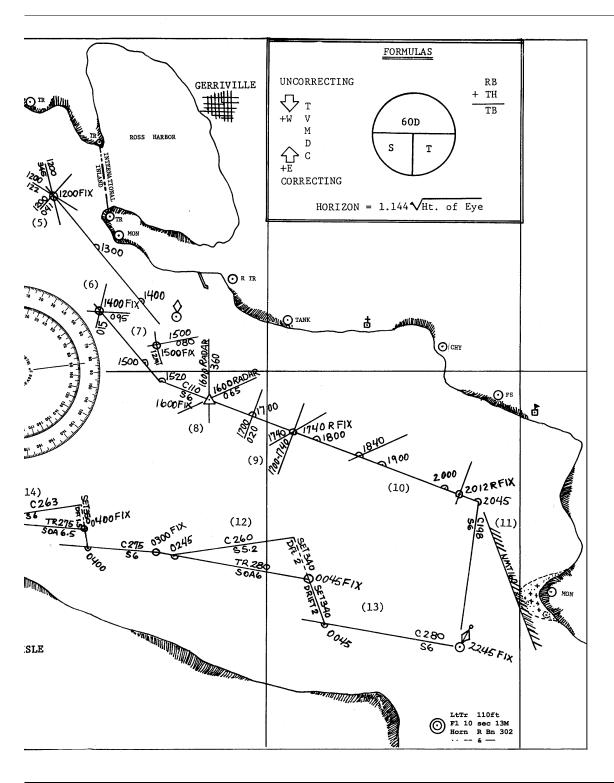
A DR plot typically includes many types of LOPs and fixes. Figure 14-43 is provided as an example of what could appear on a properly maintained DR plot. Some of the fixes within the figure have not been discussed within the text.





Sample DR Plot Figure 14-43







### Loran

#### D.60. General

Derived from the words LOng RAnge Navigation, Loran-C is a navigation system network of transmitters consisting of one master station and two or more secondary stations. Loran-C is a pulsed, hyperbolic (uses curved lines) system. Loran-C receiver's measure the Time Difference (TD) between the master transmitter site signal and the secondary transmitter site signal to obtain a single line of position (LOP). A second pair of Loran-C transmitting stations produces a second LOP. Plotting positions using TDs requires charts overprinted with Loran-C curves. However, many modern Loran-C receivers convert Loran-C signals directly into a readout of latitude and longitude, the mariner then can use a standard nautical chart without Loran-C curves. It is accurate to better than .25 nautical mile (NM).

### D.60. Receiver characteristics

Different Loran receivers have different locations of their controls, but they are basically standardized on what function is to be controlled. The boat crew should become familiar with the operation of the Loran receiver by studying its operating manual and through the unit training program.

#### NOTE &

Loran-C is not accurate enough for precise navigation, such as staying within a channel.

### D.61. Determining position

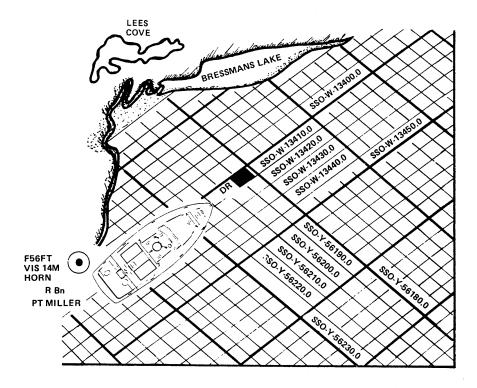
Many Loran-C receivers give a direct readout of latitude and longitude position which can be plotted on the chart. Depending on the receiver, the conversion of Loran signals to latitude and longitude may lose some accuracy. The readout typically goes to two decimal places (hundredths) but plotting normally only goes to the first decimal place (tenths).

Older Loran-C receivers display only a TD for each pair of stations. By matching these TD numbers to the Loran-C grid, overprinted on a chart, you determine an LOP. Intersecting two or more of these LOPs gives you a fix.



TDs represent specific intersecting grid lines on a Loran-C chart. (See Figure 14-44) Each line is labeled with a code such as SSO-W and SSO-Y that identifies particular master-secondary signals. Following the code is a number that corresponds to the TDs that would appear on a Loran receiver on a boat located along the line. Note the TDs and find the two intersecting grid lines; one on the SSO-W axis, the other on the SSO-Y Axis that most nearly match the readings on your boat's receiver.

The first step in plotting a Loran position is to match the numbers on the receiver with the Loran grid on the chart. The point where the two lines meet gives you a fix of your position.



- ... THE FIRST TD SSO-W-13405.0 (FIGURE 9-67) LIES BETWEEN SSO-W-13400.0 and SSO-W-13410.0
- .. THE SECOND TD SSO-Y-56187.5 (FIGURE 9-67) LIES BETWEEN SSO-Y-56180.0 AND SSO-Y-56190.0. THESE TWO TD'S PROVIDE A DR OR ROUGH FIX' THE FOUR LINES INTERSECT FORMING A GRID SQUARE. SEE FIGURE 9-69

Matching Loran TDs with Loran Grids on a Chart Figure 14-44



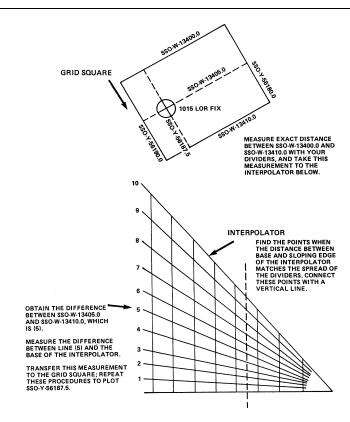
# D.62. Refining a Loran-C line of position

You have two Loran readings: SSO-W-13405.0 and SSO-Y-56187.5. The first axis lies between SSO-W-13400.0 and SSO-W-13410.0 and the second axis lies between SSO-Y-56180.0 and SSO-Y-56190.0.

Refine your Loran-C fix. (See Figure 14-45)

Step	Procedure
1	Use dividers and measure the exact distance between the Loran lines of position SSO-W-13400.0 and SSO-W-
	13410.0 on your chart. (See Figure 14-45)
2	Without changing the span of your dividers, find the points where the distance between the base of the wedge-shaped interpolator scale on the chart and the topmost sloping edge of the interpolator matches the span of the dividers. Connect these two points with a
	vertical line. (See Figure 14-45)
3	Along the vertical edge of the interpolator are the numbers 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Beginning at the base, read UP. Each number makes an immediate sloping line on the interpolator. The difference between SSO-W- 1 3405.0 and SSO-W-18410.0 is five. Select line five of the interpolator and follow it to the vertical line drawn in STEP 2.
4	Take your dividers and measure the distance between line five and the base of the interpolator. Without changing the span of the dividers measure the same distance, away and perpendicular to the line SSO-W-13400.0 on the chart nearest your DR.
	<b>Measure</b> the direction <b>toward</b> the line SSO-W-13410.0. Take your parallel rulers and draw a line parallel to S SO-W- 1 8400.0 at this point. Your SSO-W- 1 3405.0 TD is now plotted.
5	Plot the SSO-Y-56187.5 between SSO-Y-56180.0 and SSO-Y-56190.0 using the above procedure.





Obtaining a Loran Fix on a Grid Square Figure 14-45



### **Global Positioning System (GPS)**

#### D.63. General

The Global Positioning System (GPS) is a radionavigation system of 24 satellites operated by the Department of Defense (DoD). It is available 24 hours per day, worldwide, in all weather conditions. Each GPS satellite transmits its precise location, meaning position and elevation. In a process called "ranging," a GPS receiver on the boat uses the signal to determine the distance between it and the satellite. Once the receiver has computed the range for at least four satellites, it processes a three-dimensional position that is accurate to about 100 meters. GPS provides two levels of service - Standard Positioning Service (SPS) for civilians users, and Precise Positioning Service (PPS) for military users.

### **D.64. Standard** positioning service

The civilian SPS is available on a continuous basis to any user worldwide. It is accurate to a radius within 100 meters of the position shown on the receiver about 99% of the time.

## D.65. Precise positioning service

PPS provides position fixes accurate to within 21 meters. This service is limited to approved U.S. Federal government, allied military, and civil users.

### D.66. Equipment features

GPS receivers are small, with small antennas and need little electrical features power. Hand-held units are available. Positional information is shown on a liquid crystal display (LCD) screen as geographical coordinates (latitude and longitude readings). These receivers are designed to be interfaced with other devices such as autopilots, EPIRBs and other distress alerting devices, to automatically provide position information. Navigational features available in the typical GPS receiver include:

- entry of waypoints and routes in advance
- display of course and speed made good
- display of cross-track error
- availability of highly accurate time information



### **Differential Global Positioning System (DGPS)**

The Coast Guard developed Differential Global Positioning System (DGPS) to improve upon SPS signals of GPS. It uses a local reference receiver to correct errors in the standard GPS signals. These corrections are then broadcast and can be received by any user with a DGPS receiver. The corrections are applied within the user's receiver, providing mariners with a position that is accurate within 10 meters, with 99.7% probability. While DGPS is accurate to within 10 meters, improvements to receivers will make DGPS accurate to within a centimeter, noise-free and able to provide real-time updates.

The Coast Guard uses selected marine radiobeacons to send DGPS corrections to users. DGPS provides accurate and reliable navigating information to maritime users in Harbor Entrance and Approach (HEA), along U.S. coastal waters, the Great Lakes, navigable portions of the western rivers, Puerto Rico, Hawaii, and Alaska.

